REMARKS/ARGUMENTS

Favorable reconsideration of this application, as presently amended and in light of the following discussion, is respectfully requested.

Claims 15, 18, 20, 21, 23 and 25 are pending, with Claims 15 and 21 amended by the present amendment.

In the Official Action, Claims 15, 18, and 20, 21, 23 and 25 were rejected under 35 U.S.C. § 112, second paragraph; Claims 15, 18, and 20, 21, 23 and 25 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Vives; and Claims 15, 18, and 20, 21, 23, and 25 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Radjai in view of Vives.

Claims 15 and 21 are amended in response to the rejections under 35 U.S.C. § 112 and to more clearly describe and distinctly claim Applicants' invention. Support for this amendment is found in Applicants' originally filed specification. No new matter is added.

Briefly recapitulating, amended Claim 15 is directed to a method for shifting a refined microstructure of a metallic material. The method includes a) solidifying a molten metallic material within a cylindrical tube at a temperature lower than a liquidus of the molten metallic material to yield a solidifying molten metallic material; b) vibrating the solidifying molten metallic material by simultaneously applying an alternating electric current at a current value less than a current value used to melt said metallic material and a magnetic field at a Tesla value approximately equal to 1.4 Tesla to crush solid crystal particles of the solidifying metallic material into small pieces; and c) shifting the small pieces to a surface of a surrounding interior wall of the cylindrical tube with said alternating current and said magnetic field to concentrate said refined microstructure of the metallic material in an outer periphery of the solidifying metallic material.

The 1.4 Tesla is a value per square measure of a cross section of a sample. Also, the 80 Amps of Claim 21 is a value per square measure of a cross section of a sample. In one

embodiment of Applicants' invention, a sample with a 6mm diameter was used. Thus, the 80 Amps means 80 Amps/3mm x 3mm x $\pi = 2.83 \times 10^6$ Amps/m^2.

In Applicants' claimed invention, the refined particles are shifted by a "pinching force" generated by the interaction between the magnetic field and the alternating current so as to be unevenly distributed at the periphery of a cylindrical tube. The pinching force generated by Applicants' claimed invention acts against a center of radius of the sample of the molten alloy and against small particles produced. However, the small crystal particles have a lower electric conduction and thus accept a small pinching force compared with the molten alloy. Thus, the small particles are shifted to the periphery of the cylindrical tube due to the difference between the pinching force applied to the metal and the pinching force applied to the crystal particles. The shape and material of the vessel are very important elements to generate Applicants' claimed "shifting" and ceramics or glass is preferable as the material of the vessel, and the stainless steel is not preferable as the material of the vessel in this invention, but the material of the vessel is not limited to the ceramics or glass, and a cylindrical shape is preferable as the shape of the vessel. It is important to use a cylindrical tube wherein the distance to the walls of the tube is maintained uniformly against "pinching force".

The object of the present invention is firstly to provide a method for shifting a refined microstructure of a metallic material, and secondly to provide the refined microstructure of the metallic material concentrated in the periphery of the metallic material, that is the metallic material having the refined microstructure concentrated in the periphery of the metallic material. This metallic material is characterized in that the refined microstructure is shifted to the periphery of the metallic material and concentrated therein, wherein a very fine and homogeneous microstructure is only observed "in the periphery of the ingot" but not observed "throughout in the ingot".

This metallic material has a mechanical frictional sliding property due to the refined microstructure concentrated in the surface of the material and can be used preferably as automobile cylinder blocks and various types of sliding parts. Conventionally, it was impossible to obtain these material having such mechanical frictional sliding property, on the other hand, the present invention enabled us to obtain the material by using the method for the shifting a refined microstructure of a metallic material.

A benefit from the claimed invention includes an increase in quality by obtaining a finer structure in billets and slabs of steel, aluminum alloys, magnesium alloys and the like. A crystal structure having a size that is 1/l0th to $1/100^{th}$ of conventional continuous cast materials can be obtained in a simple manner. As a result, it is predicted that the strength of such billets and slabs will be increased by 2 to 3 times. Furthermore, as a result of the increased concentrated fineness of the crystal structure, the plastic working characteristics in rolling, forging, extrusion and the like are significantly improved. Accordingly, the moldability, quality and performance of various types of parts, including especially body panels and impact beams of automobiles, can be greatly improved.

Another benefit of the claimed invention concerns the presence of primary Si crystals in hyper-eutectic Al-Si alloys. Conventionally, a finer size of primary Si crystals in hyper-eutectic Al-Si alloys has been obtained by adding phosphorus (P), and the size obtained has been as small as about 30 μm. However, with the claimed invention, it is easy to obtain a size ranging from 5 μm to the sub-micron level. As a result, sliding using an oil lubricant becomes possible from conventional mechanical frictional sliding, and this technique can be applied to automobile cylinder blocks, various types of sliding parts and the like.

Another benefit concerns the fineness of crystal grain structures of magnesium alloys achievable with the claimed invention. As a result of the increased fineness of crystal grain structures of magnesium alloys, extrusion, rolling and forging of expanded materials in

particular at room temperature have become possible in the case of magnesium alloys (conventionally, working was impossible unless the temperature was 250°C or greater), and superplastical forming has also become possible. Such techniques relating to the increased concentrated fineness of crystal grain structures are applied to profiles, panel sheets, machine parts, parts for transport equipment and the like. Furthermore, material substitution has also become possible in automobile suspension parts (knuckles, differential cases, transmission cases, crankcases) and the like conventionally manufactured from steel or aluminum alloys.

Another benefit concerns the concentrated fineness of inclusions achievable with the claimed invention. Inclusions that are generated in the casting of steel, aluminum alloys and magnesium alloys can also be made finer, and problems such as a drop in elongation, deterioration of toughness, drop in strength, cracking and the like conventionally arising due to the presence of inclusions are rendered harmless by this increased concentrated fineness, so that such phenomena are no longer problems.

Another benefit concerns materials used in semi-solid processes achievable with Applicants' invention. In semi-solid process, it is necessary that materials (billets, ingots or the like) in which fine spherical solid-phase particles are formed be worked at a semi-molten temperature. In materials that are currently supplied, uniformly fine spherical solid-phase particles are not formed; accordingly, the quality of the molded products does not manifest the initial characteristics. Furthermore, this problem is accompanied by the problem of poor moldability.

In general, with the claimed invention, the primary crystal solid-phase particles can easily be made extremely fine; furthermore, since electromagnetic vibrations are applied during solidification, the solid-phase particles are made spherical and concentrated. Accordingly it is possible to manufacture materials in which fine spherical solid-phase

particles are concentrated, which cannot be obtained using other methods. This is also a process for supplying materials for use in semi-solid molding.

Supplemental Fig. 1 (attached hereto) shows a stage of solidification started and a stage of final structure. In the stage of the final structure, the small pieces are shifted to the surface of the surrounding walls of a cylindrical tube, that is, a periphery of the metallic material and concentrated in an end portion of said metallic material. Supplemental Fig. 2 (attached hereto) shows a "pinching force" generated by Applicants' claimed invention which acts against a center of radius of the sample of the molten alloy. Fig. 3 shows a possible mechanism of continuous refinement process wherein a cylindrical tube is used by applying the present invention.

Turning now to the outstanding rejections, Vives discloses a magnetohydrodynamic method for transmitting forced vibrations to solidifying aluminum alloy. Vives notes that "the magnetohydrodynamic phenomena occurring during the tests are rather complex and will not be thoroughly examined."[1] The reference goes on to note that the purpose of the study is "restricted to the presentation of the main characteristics of the fluid flow in an attempt to follow the evolution of both the size and shape of the grains during solidification." Vives fails to disclose or suggest Applicants' claimed step of "shifting the small pieces to a surface of a surrounding interior wall of the cylindrical tube with said alternating current and said magnetic field to concentrate said refined microstructure of the metallic material in an outer periphery of the solidifying metallic material."

In Vives, an electric current and a magnetic filed are simultaneously applied to a metal sample in a vessel having free surface (i.e., a vessel without a cover).[2] Because of this free surface, the previously described pinching force cannot be successfully generated. Also, even if a reduced pinching force were to be generated in the vessel, the pinching force will be

[1] Vives, page 446, right column, in the paragraph beginning on line 22.
[2] Vives, Figure 3.

scattered and lost through the free surface. On the other hand, with Applicants' claimed cylinder by definition has no "free surface." Thus, Applicants applied electric current and magnetic field can generate the previously described pinching effect, resulting in Applicants' claimed step of shifting and ***concentrating***.

Furthermore, the vessel used in Vives is made of stainless steel. Thus, some of the electric current of Vives passes through vessel itself to produce Joule heat which cases great loss of the electric current impressed. Induced magnetic field for generate pinching force is absorbed to the stainless steel of the vessel and thereby pinching force can not be generated. Also, in Vives the strength of the magnetic field in Vives is about 1/10 compared with that of the present invention. Therefore, the effect of the magnetic field is greatly different between Vives and the claimed invention. That is, in the claimed invention, the electric field and magnetic field act to apply electromagnetic vibrations to the molten metal at a magnitude sufficient to cause the "shifting" of the metal particles. Applicants' claimed "shifting" cannot occur with the stainless steel vessel in Vives and with the low power magnet of Vives. In other words, Vives does not disclose or suggest a Tesla value capable of Applicants' claimed shifting.

Applicants' acknowledge that "Vives discloses as grain refinement method for aluminum alloy by applying an electric current and a magnetic field simultaneously to the molten aluminum alloy during a solidification process at temperature lower than a liquidus of the alloy". However, for at least the foregoing reasons, Applicants traverse the assertion that the process of Vives "will produce the same results as that of Applicants since he performs the identical process steps as that of Applicants" and that "...Vives substantially shows the invention as claimed except that he does not show the container is in cylindrical shape [but that] it would has been obvious to use container of any configuration in the process of Vives depending on the designated metallic casting article to be objected".

Vives discloses effects of forced electromagnetic vibrations during the solidification of aluminum alloys, in the presence of crossed alternating electric fields and stationary magnetic fields, where Fig. 2 shows principle of production of forced electromagnetic vibration in solidifying melt, and Fig. 3 shows schematic sketch of the experimental device: (a) view from above and (b) front view. Further, Vives discloses that the crucible, whose internal dimensions were 2 x 4 x 12 cm, is stainless steel and the pool is hermetically closed by an upper horizontal wall made of stainless steel and covered by a ceramic insulator (page 447, 3rd paragraph). Further, Vives discloses that "In the presence of well-developed cavitation situations, a very fine and homogeneous microstructure has obtained by alternating electric fields and stationary magnetic fields in Vives.

However, Vives teaches that the very fine and homogeneous microstructure has been observed "***throughout*** the ingot", (page 445, abstract, lines 7-8) or "***through*** the vibrated ingots" (page 451, right col., lines 8-9 from the bottom), or "***through*** the irradiated ingot" (page 454, left col., lines 5-9 from the bottom), which shows apparently that the refined material is ***not shifted*** to a periphery of the device. This very important admission conclusively proves that Vives himself realized that his process could not produce the same results as that of applicants. In effect, Vives teaches away from Applicants' claimed invention by teaching a fine and homogeneous structure throughout the ingot, rather than just at the periphery. For these reasons, Applicants also traverse the assertion that "it is expected that Vives also will have a shifting step, even though the intensity of shifting might be different".

Finally, the shape and materials of the container or vessel are very important elements to generate Applicants' claimed "shifting." For ease of understanding, Figure 3 of this paper shows Applicants' claimed cylindrical metal sample inserted in an insulated container made of ceramics or glass. This sample is melted, subjected to electromagnetic vibrations, and

solidified to produce refined metal particles. The electromagnetic vibrations and previously described pinching force act against the metal particles to shift the initial crystallized silicon particles in the container to the surrounding walls.

As seen in Figure 4 of Vives, a metal sample is inserted in a ***rectangular*** container with open upper part (free surface) made of stainless steel. This sample is melted, subjected to electromagnetic vibrations, and solidified. The electromagnetic vibrations of Vive act on the metal sample. However, the generated pinching force ***escapes from the open upper part of the container***. Thus, Applicants' claimed "shifting" of the metal sample ***does not occur*** with the invention of Vives.

With regard to Applicants' invention, the common radius of a cylinder makes it possible to shift the small pieces to a periphery of a cylindrical tube. In contrast, it is quite difficult to shift the small pieces to a periphery of a rectangular container shown in Fig. 2 and 3 in Vives without concentrating particles in the corners of the rectangle.

Vives also does not disclose Applicants' claimed 1.4 Tesla.

Thus, in view of the preceding discussion and Applicants' amendment to Claims 15 and 21, Applicants request that the rejection under 35 U.S.C. § 103(a) be withdrawn.

Turning now to the rejection under 37 U.S.C. § 103(a) based upon Vives and Radjai, Radjai discloses a method where "Vibrations were induced in a hyper-eutectic Al-Si alloy containing suspended silicon particles and the effects were studied" and that "Suspended silicon particles multiplied in number with a reduction in size by vibrations at temperatures higher than the liquidus and agglomerated and repelled to the outer surface after the start of solidification". In the method of Radjai, a molten hyper-eutectic Al-Si alloy which contains suspended silicon particles added thereto is used as sample. The Al-Si alloy is heated to produce molten state of alloy, with solid silicon particles added thereto, and then electromagnetic vibrations are applied to the alloy to multiply the suspended silicon particles

in number. Thereby the particles are agglomerated so as to be enlarged and repelled to the outer surface where the resistance against the macro-flow is smaller. Thus, Radjai does not disclose "vibrating the solidifying molten metallic material by applying an alternating electric current and a magnetic field simultaneously at a current value and a Tesla value configured to crush solid crystal particles of the solidifying metallic material into small pieces."

Like Vives, Radjai fails to disclose Applicants claimed "shifting the small pieces to a surface of a surrounding interior wall of the cylindrical tube with said alternating current and said magnetic field to concentrate said refined microstructure of the metallic material in an outer periphery of the solidifying metallic material" for the following reasons:

As noted previously, in Applicants' claimed invention the refined particles are shifted by a "pinching force" generated by the interaction between the magnetic field and the alternating current so as to be unevenly distributed at the periphery of a container. The pinching force generated by Applicants' claimed invention acts against a center of radius of the sample of the molten alloy and against small particles produced previously. However, the small (e.g., silicon crystal) particles have a lower electric conduction and thus accept a smaller pinching force compared with the molten alloy. Thus, Applicants' small particles are shifted to the periphery of a container due to the difference between the pinching force applied to the metal and the pinching force applied to the crystal particles. In Radjai, macro-flow effects may be generated as well. However, with Applicants' claimed method, the flow resistance of Applicants' small particles is less than the flow resistance of the agglomerated and enlarged particles produced by Radjai. Therefore, Radjai's small particles are not repelled to the outer surface but are unevenly distributed in the sample.

In Radjai, the suspended silicon particles remain solid state in the molten alloy, whereas in the present invention, the completely molten alloy is cooled to solidify the sample (see Fig. 1 attached hereto). Thus, for another reason, the particles generated in the present

invention are smaller than the silicon particles produced by the method of Radjai, further facilitating Applicants' claimed shifting.

The Official Action asserts that "Radjai substantially show the invention as claimed except they does not disclose to crush solid crystal into small pieces during a solidification process at temperature lower than the liquidus". Applicants concur. The Official Action further recites that "however, Vives discloses two distinct causes of grain refinement, represented by fluid flow and cavitation phenomena, in a solidifying liquid metal. In the absence of cavitation and for a sufficient intensity of the oscillating flow, the columnar-dendritic crystallization is replaced by a microstructure characterized by the formation of agglomeration of globular particles. On the other hand, when an alloy is solidified in the presence of well-developed cavitation situations, a very fine and homogeneous microstructure has been observed throughout ingot. He also discloses that gas content in the liquid metal and the intensity of magnetic pressure contributed to the cavitation phenomena". Applicants again concur.

The Official Action further asserts that "It would have been obvious to manipulate the gas content of aluminum alloy and the magnetic pressure during the solidification process of Radjai in view of Vives such that to obtain well-developed cavitation situations in the molten metal at the temperature lower than the liquidus and thereby to better refine the grain structure". Applicants traverse. However, assuming *arguendo* that the preceding statement is correct, if it would have been obvious to manipulate the gas content of aluminum alloy and the magnetic pressure during the solidification process of Radjai, such a modification would only result in a better refining of the grain structure. Such a modification would not result in Applicants' claimed shifting of the small pieces.

However, in the method of Radjai, a molten hyper-eutectic Al-Si alloy which contains suspended silicon particles added thereto is used as a sample. That is, the Al-Si

alloy is heated to produce molten state of alloy, solid silicon particles are added thereto, and then electromagnetic vibrations are applied to the alloy to multiply the suspended silicon particles in number. Thereby the particles are agglomerated/enlarged and repelled to the outer surface. Thus, the suspended silicon particles are multiplied in number with a reduction in size and then are agglomerated/enlarged again by an agglomeration of the multiplied particles, and then the enlarged particles are repelled to the outer surface because the flow resistance in the outer surface is smaller compared with the macro-flow generated in the sample by the vibrations.

In contrast, in the present invention, for example, A1-Si alloy is completely molten, and then an alternating electric current and a magnetic field are applied to as the sample begins to solidify. Thus, the solid crystal particles of the solidifying metallic material is crushed into small pieces <u>without generating agglomeration and enlargement thereof</u>, and the small pieces are shifted by "pinching force" generated according to interaction between induced magnetic filed and alternating electric current to be unevenly distributed at the periphery of a tube.

The pinching force acts against a center of radius of the sample of the molten alloy together with the silicon crystals. However, the silicon crystal particles have a lower electric conduction and therefore accept a smaller pinching force than the molten alloy. Thus, the silicon particles are shifted to the periphery of a tube due to the difference of the pinching force.

In the present invention, "shifting" is generated by a pinching force which is different based on <u>the size of the particles</u>. In these cases, a macro-flow is generated as well. However, the flow resistance of the silicon particles not agglomerated is smaller than that of the silicon particles as being agglomerated. Therefore, the silicon particles not agglomerated are smaller than the silicon particles being agglomerated so that the silicon particles not

agglomerated are not repelled to the outer surface but are distributed at an edge portion of the sample.

To contrast, the phenomenon of "repulsion" in Radjai occurs by the particles being agglomerated/enlarged by accepting a macro-flow in the sample, whereas the "shifting" in the present invention occurs by crushing (and not agglomerating) small pieces via the pinching force. Radjai discloses only "repulsion" of the particles being agglomerated/enlarged but nothing about "shifting" due to the pinching force. In view of the above, one skilled in the art would appreciate that the "repulsion" in Radjai is substantially different from the "shifting" of the present invention.

The Official Action further asserts that "It would have been obvious to use the container of any configuration in the process of Vives depending on the designated metallic casting articles to be obtained." Applicants traverse.

In the present invention, an electric current and a magnetic field are simultaneously applied to a solidifying molten metal in a cylindrical tube which has no open surface (i.e., no surface corresponding to free surface as in Fig. 2 in Vives). In contrast, in Vives an electric current and a magnetic field are simultaneously applied to a metal sample in a vessel having a square shape and "free surface" (i.e., not covered) as described in Fig. 3 in Vives.

Because in Vives, a vessel having the square shape and free surface is used, any force generated that could evolve into a pinching force is scattered and lost through the free surface. Therefore, a pinching force in the vessel with a square shape and free surface can not be generated successfully. Furthermore, even if a pinching force can be generated in the vessel of Vives, the pinching force would be highly attenuated due to the square and the free surface, and thus, would have a very limited ability to shift the silicon particles to a surface of a surrounding interior wall of the vessel because the silicon particles are not dispersed uniformly in the periphery of the wall of the vessel.

On the other hand, in the present invention, the cylindrical tube has a surrounding interior wall with a common radius. Thus, the metal particles are shifted to a periphery of the tube by applying an electric current and a magnetic field simultaneously to the metal particles in the present invention. In this case, a cylindrical tube is used to cause the small pieces to shift to the surface of a surrounding interior wall of the cylindrical tube in a more even distribution.

In Vives, a normal electromagnet is used to produce magnetic field. The strength of the magnetic field in Vives is about 1/10 compared with that of the present invention. Therefore, the effect of the magnetic fields are greatly different between Vives and the present invention.

Applicants submit that the present invention is not obvious in view of Vives and Radjai. because both Radjai and Vives fail to disclose all the features of Applicants' claimed invention.

Accordingly, in view of the present amendment and in light of the previous discussion, Applicants respectfully submit that the present application is in condition for allowance and respectfully request an early and favorable action to that effect.

Respectfully submitted,

OBLON, SPIVAK, McCLELLAND,
MAIER & NEUSTADT, P.C.

Gregory J. Maier
Attorney of Record
Registration No. 25,599

Michael E. Monaco
Registration No. 52,041

Customer Number
22850

Tel: (703) 413-3000
Fax: (703) 413 -2220
(OSMMN 03/06)

I:\ATTY\MM\AMENDMENT\163\01630707-AM2.DOC

SUPPLEMENTAL DRAWING FIGURES 1-3